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A review of information relevant to the issue of consumption of Atlantic cod *(Gadus morhua)* by seal species in the southern Gulf of St. Lawrence

M. Hammill, J.F. Gosselin, F. Proust and D. Chabot

Department of Fisheries and Oceans, Institut Maurice-Lamontagne
Mont Joli Quebec, G5H 3Z4, Canada

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Abstract

Four species of seals: grey seals (*Halichœrus grypus*), harbour seals (*Phoca vitulina*), harp seals (*Phoca groenlandica*) and hooded seals (*Cystophora cristata*) occur in the southern Gulf of St. Lawrence. Harp seals and grey seals are the most important seal predators owing to their abundance (harp seals), or time of residency in this area and possibly high incidence of cod in the diet (grey seals). Harbour seals and hooded seals are less important predators in this region owing to their small numbers. Pinniped consumption of cod in 4T may be in the order of 5,000-13,000 t, but these estimates should only be considered as very tentative. The absence of comprehensive diet information for pinnipeds in the southern Gulf, is one of the major factors limiting attempts to quantify groundfish consumption in this area. Furthermore, the impact of predation on 4T cod stocks cannot be evaluated until predation is considered within the context of total natural mortality.

Résumé

On retrouve quatre espèces de phoques dans le sud du Golfe du Saint-Laurent : le phoque gris (*Halichœrus grypus*), le phoque commun (*Phoca vitulina*), le phoque du Groenland (*Phoca groenlandica*) et le phoque à capuchon (*Cystophora cristata*). Les phoques du Groenland et les phoques gris sont les prédateurs les plus importants en raison de leur abondance (phoques du Groenland), ou de leur temps de résidence dans cette zone ainsi que par la proportion possiblement élevée de morues dans leur régime alimentaire (phoques gris). Les phoques communs et les phoques à capuchon, en raison de leur faible nombre, sont des prédateurs moins importants dans cette région. La consommation de morues par les Pinnipèdes dans la zone 4T pourrait être de l'ordre de 5 000 à 13 000 tonnes, mais ces estimations ne doivent être considérées que provisoires. L'absence d'information détaillée sur le régime alimentaire des Pinnipèdes dans le sud du Golfe est l'un des principaux facteurs limitant l'estimation de la consommation de poissons de fond dans cette zone. De plus, l'impact de la prédation sur les stocks de morues de la zone 4T ne pourra être évalué que si la prédation est considérée dans un contexte de mortalité naturelle totale.

Introduction

Over the last 10 years, the progressive increase of seal populations and the low abundance of groundfish populations has raised concerns of the impact of seal predation on these populations and in particular on Atlantic cod. Four species of seals are common throughout Atlantic Canada waters. These four species: grey seals (*Halichoerus grypus*), harbour seals (*Phoca vitulina*) harp seals (*Phoca groenlandica*) and hooded seals (*Cystophora cristata*) (Mansfield 1967) are all found in the southern Gulf of St. Lawrence. The following is a review of the available information relevant to the issue of consumption of cod in the southern Gulf of St. Lawrence by these four species.

I. Harp seals

A. Abundance

Harp seals are the most abundant of the four species with an estimated NW Atlantic population of almost 5 million animals in 1994 (Stenson et al. 1999). This species is harvested commercially with an annual quota of 275,000 animals.

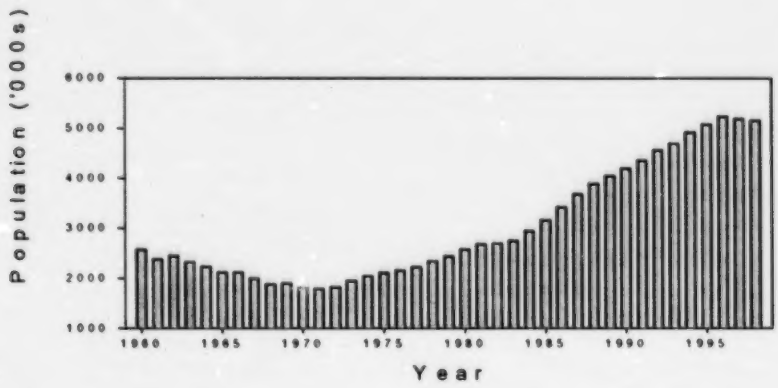

Figure 1. Estimated change in abundance of NW Atlantic Harp seals between 1960 and 1998.

B. Biology, distribution and movements

Harp seals are medium sized members of the phocid family weighing about 130 kg during the breeding season. They are a migratory, pelagic species. During the summer the majority of the population is found in the Canadian Arctic and/or off west Greenland, but a small proportion of the population remains in the northern Gulf of St Lawrence and off Newfoundland year round. During the fall or early winter harp seals move southward along the Labrador coast, and into the Gulf of St Lawrence in early December (Sergeant

1991). According to tag recoveries from the hunt, the fraction of the population entering the Gulf of St Lawrence varies between years from 13% to 51%, but the long-term average is around 39% (Winters 1978). It is thought that most animals follow the north shore towards the west, with some animals moving as far as the Saguenay river region in the Estuary (Fig 2). However, Harp seals are seen throughout the Gulf during the winter, and in recent years beaters have been observed hauled out on the pack ice off the west coast of Cape Breton Island during studies on grey seals in January (Hammill unpublished data). Unfortunately, there is no information on the relative distribution of animals between the northern gulf (NAFO Divisions 4R,S), and the southern Gulf and the estuary (NAFO 4T).

Whelping occurs on the pack ice in the Gulf of St Lawrence, near the Magdalen Islands or off the southern Labrador coast in March (Fig. 3). Lactation lasts for approximately 12 days. When the pups are weaned, the adults mate and females disperse to feed intensively for a brief period of approximately one month where they replace some of the energy reserves used up during lactation. Adult males appear to remain in the region of the whelping patch until late March, but do not appear to feed intensively at this time (Beck et al 1993a). In the southern gulf, the whelping patch normally originates about 45 miles north of Cap aux Meules in the Magdalen Islands. However, the location varies with ice conditions. In 1998, suitable ice conditions, which consist of areas with at least 90% total cover, but with ice ≥30 cm thick accounting for at least 50% of the total ice cover occurred off the northwestern coast of Prince Edward Island. In 1969 whelping occurred on the north coast of PEI and in Northumberland Strait (Sergeant 1991).

Some animals are seen hauled out on the ice at the beginning of February, but pupping does not begin until about the 23 February. During March, portions of the patch may drift past the northern part of the Magdalen Islands and drift out through Cabot Strait, while the majority of animals drift down the west side of the islands and around the south end before drifting out through Cabot Strait in April. Beginning in early April, juveniles and adult males start to moult on the pack ice around the Magdalen Islands or in the northern Gulf of St Lawrence (Sergeant 1991). Females moult slightly later. After the moult has finished harp seals return to the north during May-June. Satellite telemetry work carried out on 6 seals early in the 1990's supported the above pattern, with the exception that not all females moved to the Les Escoumins area to feed after weaning their pups. Some animals appeared to follow the ice edge towards the deep trench off Baie de Chaleur. A young animal approximately 2 years old was fitted with a satellite transmitter on 25 December 1998 in Blanc Sablon. At the end of January, he had moved into NAFO Zone 3Pn and by early February he was on the Tail of the Grand Banks in NAFO zone 3N.

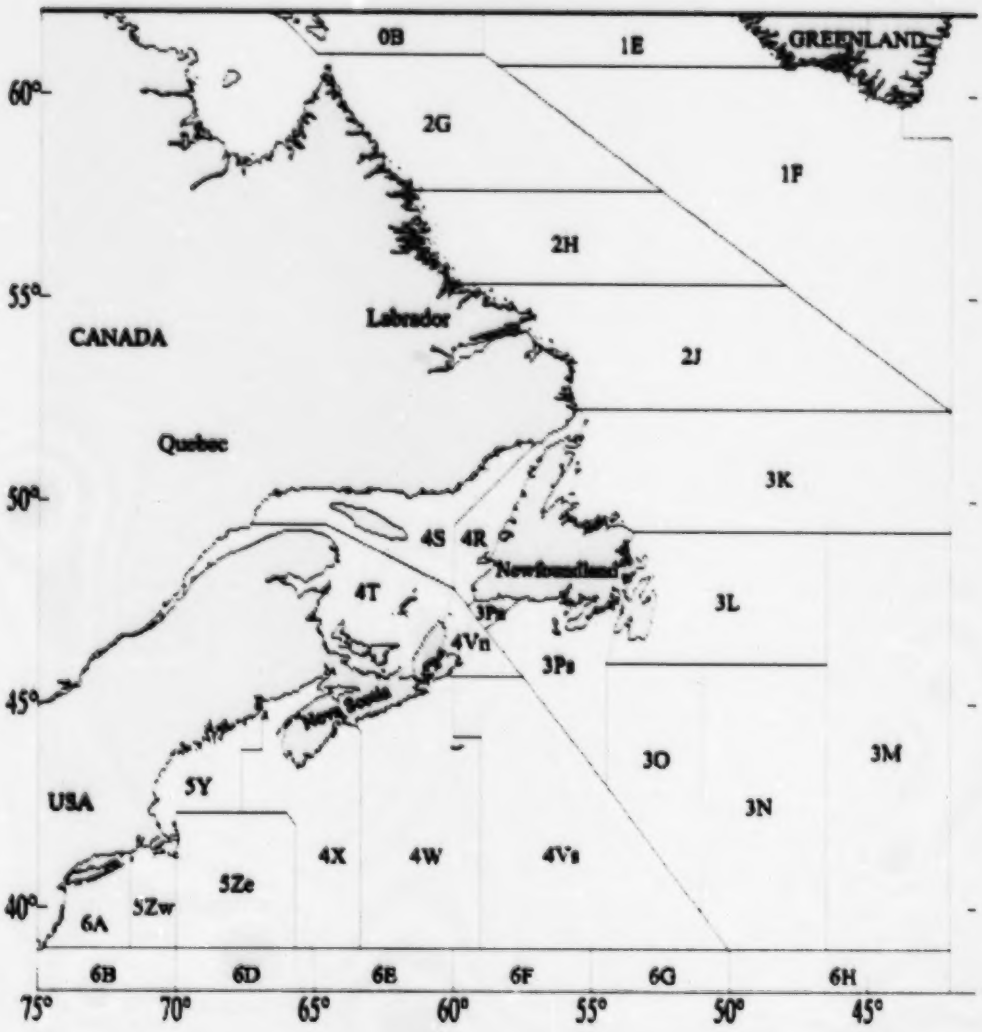

Figure 2. Location of Northwest Atlantic Fisheries Organization (NAFO) fishing zones.

C. Diet

Studies of harp seal diet have concentrated on sampling from the St Lawrence estuary and the west coast of Newfoundland (Murie and Lavigne 1991; Beck et al. 1993b; Lawson et al. 1995; Stenson unpubl.). Some sampling has occurred in the southern gulf (4T), but this has been directed towards sampling in March during whelping, when adults reduce their food intake (Table 1)(Sergeant 1973; Stewart and Murie 1986; Beck et al 1993). Attempts to compare diet composition between studies are complicated because methods of analysing and presenting the data have changed since the 1970's. In four stomachs collected during March 1952 and 1954, no cod were found. Using the metric, percent of stomachs containing prey (N=120), the amount of herring increased from 19% of the stomachs collected from animals shot in late March to 93% of the stomachs sampled in May 1956. Less than 1% of the stomachs contained Gadids (Sergeant 1973) . No cod were reported in a sample of 45 food containing stomachs collected from the whelping patch during March between 1976 and 1984 (Stewart and Murie 1986). Sixty-two food containing stomachs collected in March 1989, contained primarily invertebrates such as Mysids, and Decapods but no cod (Beck et al 1993). Sampling on the whelping patch in early March has continued since 1990 (N=181), but this material has not been analysed.

Harp seals consume very small cod. Seventy-two percent of cod consumed by harp seals off the west coast of Newfoundland were ≤20 cm long, 18% were 20-30 cm, 8% were 30-40 cm long and 2% were ≥ 40 cm (Lawson et al 1995).

The limited data that do exist suggest that cod is a very minor component of the 4T harp seal diet. If the cod in the diet is on the order of 1%, then harp seals in 4T may have consumed about 2,000 t of cod. However, this is only a very rough estimate and is very much affected by the actual proportion of the Gulf harp seal population present in 4T, and the importance of cod in the diet.

Table 1. Diet composition of harp seals in the Gulf of St Lawrence expressed as % number of stomachs containing a prey item. Data are from [1]Murie and Lavigne (1991), [2]Beck et al 1993, [3] Sergeant 1973 and [4]Lawson et al (1995).

	Estuary[1] Jan-Feb 1983	Magdalen Islands[2] March 1989	Magdalen Islands[3] Mar-May, 1956	West. NFLD[4] Oct-Sept. 1990-93
Cod	4	0	<1	14
Herring	0	0	54	13
Redfish	16	0	0	9
Flatfish	0	8	6	5
Capelin	100	0	0	40
Invertebrates	28	90	1	6
N	25	62	120	139

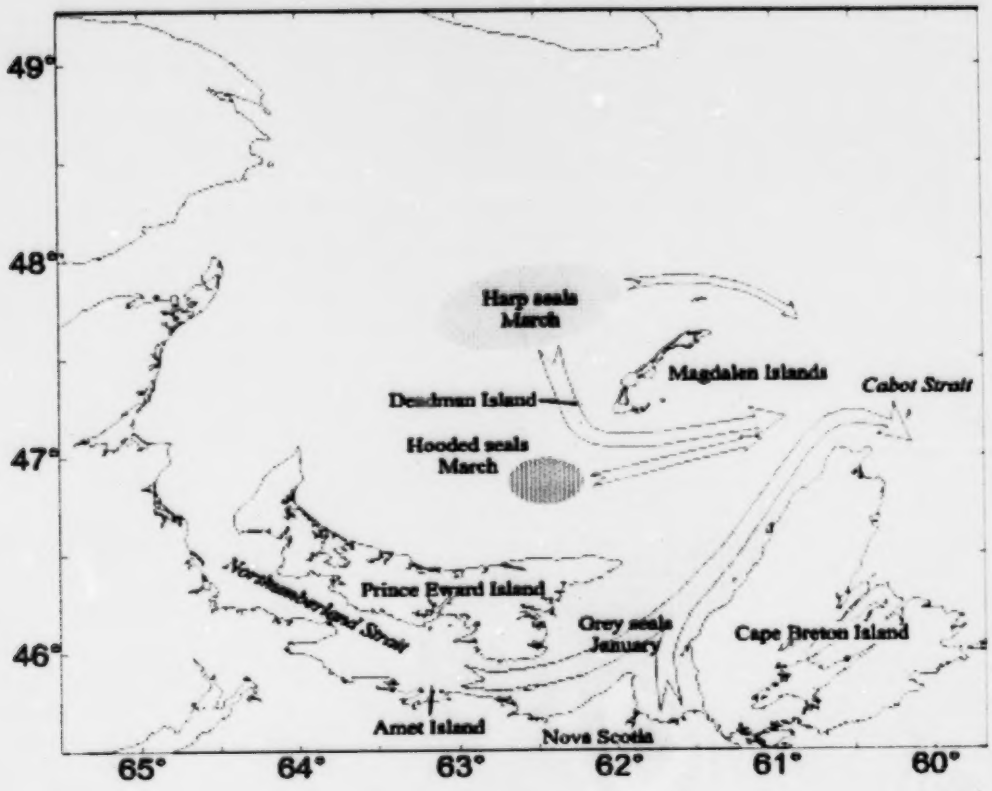

Figure 3. General location of Harp, Hooded and Grey seal whelping patches in the southern Gulf of St Lawrence and general direction of the drift of these patches as the season progresses.

II. Hooded seals

A. Abundance

Hooded seals are the second most abundant pinniped in Atlantic Canada, with a total population of around 500,000 animals (Hammill and Stenson In press). Hooded seals are hunted commercially off Newfoundland, but are protected in the gulf where they are much less abundant (≤16,000 animals: Hammill et al 1997). No data is available on changes in hooded seal abundance in the Gulf. The stock relationships between the front and Gulf hooded seals are not understood, but they may form two different groups.

B. Biology, distribution and movements

Hooded seals are the largest of the 4 pinniped species. Adults on the whelping patch may weigh up to 300 kg in the case of females or 430 kg in the case of males (Hammill unpublished data). Hooded seals are highly migratory. The majority of the population summers off Greenland. They move southward along the Labrador coast, during the fall or early winter and into the Gulf of St Lawrence in December . Hooded seals are seen throughout the Gulf during the winter, and in recent years bluebacks (animals <14 months old) have been observed hauled out on the pack ice off the west coast of Cape Breton Island during studies on grey seals in January (Hammill unpublished data; 1993). Whelping occurs on the pack ice between Prince Edward Island and the Magdalen Islands in the Gulf of St Lawrence (Fig. 3), or off the southern Labrador coast in March. Lactation lasts for 4 days (Kovacs and Lavigne 1992). When the pups are weaned, the adults mate and then females disperse, presumably to feed intensively for a brief period along the north slope of the Laurentian Channel between the southwest tip of Newfoundland and Sept-Iles (G. Stenson and M. Hammill, unpubl. data). Adult males appear to remain in the region of the whelping patch until late March and then move to the northern gulf similar to the females. Moulting occurs in June/July off the Greenland coast (Sergeant 1976).

C. Diet

No information is available on hooded seal diet composition in the Gulf. Off Newfoundland they feed primarily on Greenland Halibut, Redfish, Herring and Arctic cod (Table 2).

Table 2. Hooded seal diet composition (% wet weight) used to estimate prey consumption (Hammill and Stenson 1997).

Species	2J3KL Inshore	2J3KL Offshore
Atlantic cod	1.2	10.1
Herring	14.0	
Capelin	0.3	0.9
Witch		15.5
Greenland Halibut	42.2	31.6
Redfish	20.6	3.3
Pleuronectidae		8.3
Squid	7.2	12.6
Arctic cod	14.5	
Grenadier		5.7
Blue hake		4.2
Lancetfish		1.6
Eelpout		0.4
Other Fish		5.8
Mean Energy (kj/g)	5.38	5.25

III.Grey seals

A. Abundance

Grey seals early in this century were rare (Lavigueur and Hammill 1993). Two major groups are recognized based on the location of their principal whelping sites. The largest colony whelps on Sable Island. This colony is increasing at a rate of ≈13% per year. Pup production has increased from 1,000 in 1970 (Mohn and Bowen 1996) to around 25,000 animals (95% C.I. 24,000-27,000) in 1997 (Bowen et al 1999), while total population of the Sable Island component has increased from around 5,000 in the early 1970's (Mohn and Bowen 1996), to 145,000 animals in 1997 (Hammill 1999)(Fig 3). The second largest group of grey seals, referred to as Non-Sable Island animals or Gulf animals, whelp primarily on the pack ice in the southern Gulf of St Lawrence. Other small colonies are found on small islands in the southern gulf or off the Nova Scotia Eastern Shore. The dynamics of this population appear to differ substantially from Sable Island owing to higher and more variable pup mortality rates resulting from the variability in ice conditions and to a bounty and culling program which operated throughout the 1970's to 1992 (Hammill et al 1998). Recent aerial surveys estimate 1996 and 1997 pup production to be between 7,000 (95% C.I. 5,000-10,000) and 12,000 (95% C.I. 7,000-17,000) animals (Hammill et al 1999).

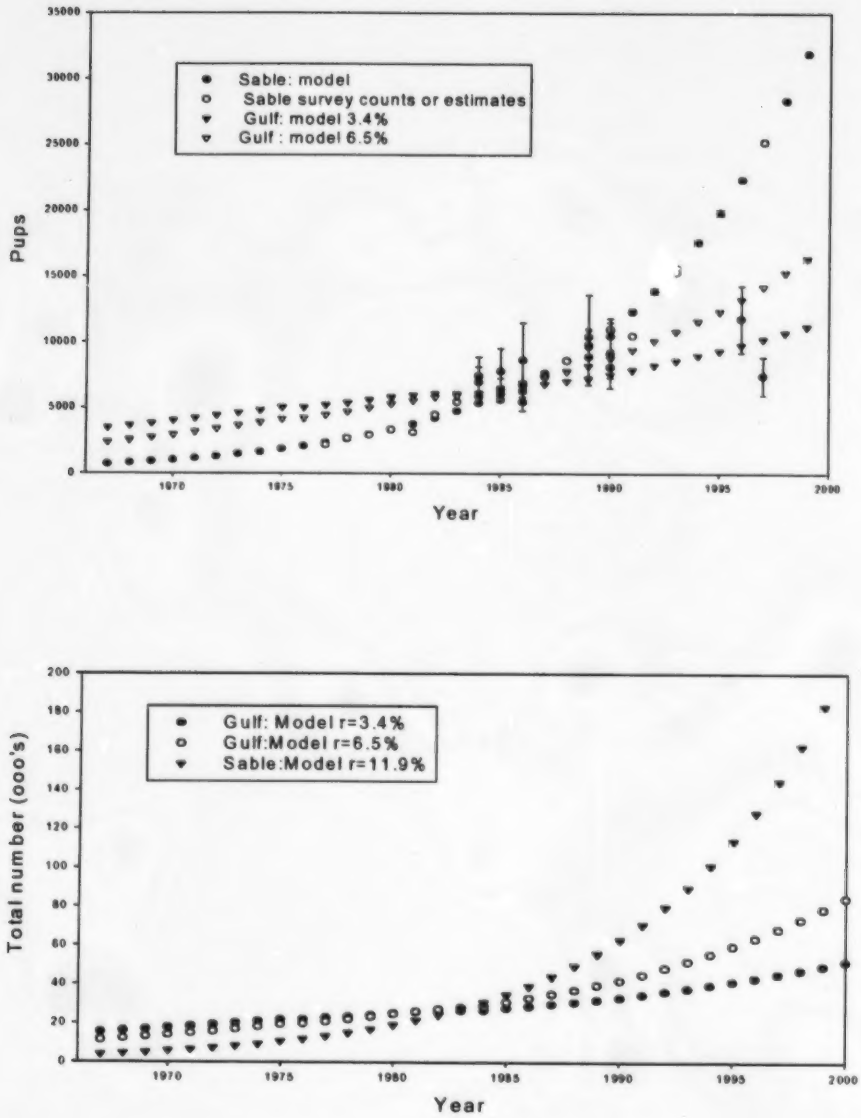

Figure 4. Estimates of Northwest Atlantic grey seal pup production and modelled changes pup abundance (top), and total population size (bottom) from 1967 to 1999. The trajectory for the Gulf component was modelled using the estimated rate of increase (r=3.4), and the upper 95% confidence limit of r=6.5 (Hammill 1999).

From a series of mark-recapture experiments conducted in 1984-1986, 1989-1990 and including the new aerial survey data, this component of the population is increasing at a rate of ≈3.4% per year (SE=0.02; Hammill et al 1999) (Fig. 4). Attempts to model the dynamics of this population suggest that pup production has increased from 5,000 animals in 1970 to 11,000 in 1997, and total population has increased from 21,000 in 1970 to 47,000 in 1997 (Hammill 1999). In 1970, the Gulf component formed 73 % of the total population (Mohn and Bowen 1996). Currently, Gulf grey seals make up 32% of the total population of about 190,000 animals (Fig. 4).

B. Biology, distribution and movements

Grey seals are slightly smaller than hooded seals. During the breeding season females weigh about 230 kg, while males may weigh around 380 kg. The pups are born between the end of December and early February. Lactation lasts for about 16 days. Females whelping on land tend to remain with their pups all of the time, while animals whelping on the ice will feed during lactation (Baker et al. 1995).

In the Gulf, whelping occurs on the pack ice in the Northumberland Strait, Prince Edward Island-Cape Breton Island area of the southern Gulf of St Lawrence, on Deadman Island near the Magdalen Islands or on Amet Island (Fig. 3). At the end of the whelping season, the adults disperse offshore to feed and then return to land to moult during April-June. Once moulting has finished they disperse to summer regions until fall, when they return to the whelping sites. Adults show strong site fidelity to their whelping sites with a rate of exchange between sites of around 5% (Zwanenburg and Bowen 1990). However, during the summer they disperse widely, with animals from Sable Island moving into the Gulf, and Gulf animals moving out onto the Scotian Shelf (Stobo et al. 1990; Lavigueur and Hammill 1990). Current views on the seasonal distribution are based on a combination of tag returns, aerial surveys and observations (Stobo et al 1990; Lavigueur and Hammill 1993; Clay and Nielsen 1983)(Table 3). These views are limited by the distribution of sighting and hunting efforts (Stobo et al 1990; Lavigueur and Hammill 1993).

Movements and diving activity of grey seals in the Gulf and on Sable Island have also been monitored using satellite telemetry. In the Gulf, satellite tranmitters were deployed on 24 grey seals between January 1993 and May 1998. Animals were captured using a large gill net, tranquilized and the transmitters were attached to the fur near the head using a 5 minute epoxy glue. Twenty-one animals were captured in late summer (August-September), three were captured on the pack-ice during January off the west coast of Cape Breton Island. The telemetry data supported the general observations obtained from the tagging studies. During August to November movements of Gulf grey seals were largely coastal. Adults tended to frequent the same haulout sites, with periodic movements away from the coast which are probably associated with foraging (Fig. 4), while juveniles tended to range further (Fig. 5). From mid to late November, there was a definite movement of animals from the northern Gulf

towards the main traditional whelping areas in the southern Gulf and Sable Island. This shift in distribution movement has been identified by aerial surveys (Clay and Nielsen 1983), but the migration occurs rapidly, with seals moving from Anticosti to the southern Gulf or the Scotian Shelf in 8-14 days in the case of adults, while the movement was more protracted for some juveniles (6-26 days). By December almost all animals have left the northern Gulf and have moved to the southern Gulf of St Lawrence or onto the Scotian Shelf (Fig 5,6). During January-February, there is a movement of both adult and juvenile animals out of the Gulf through Cabot Strait to the Scotian Shelf. At this time grey seals enter a more pelagic phase with 17/18 moving more than 80 km offshore and remaining offshore for up to one month (maximum 53 days).

Table 3. Seasonal distribution of Gulf of St. Lawrence and Sable Island grey seals based on resightings, tag returns and aerial surveys.

	Gulf herd					Sable herd			
	Q1	Q2	Q3	Q4		Q1	Q2	Q3	Q4
N_Gulf	0.1	0.35	0.6	0.5	N_Gulf	0	0.125	0.075	0.05
S_Gulf	0.7	0.35	0.1	0.3	S_Gulf	0	0.125	0.075	0
4VsW	0.1	0.2	0.2	0.1	4VsW	0.9	0.5	0.5	0.8
Other	0.1	0.1	0.1	0.1	Other	0.1	0.25	0.35	0.15

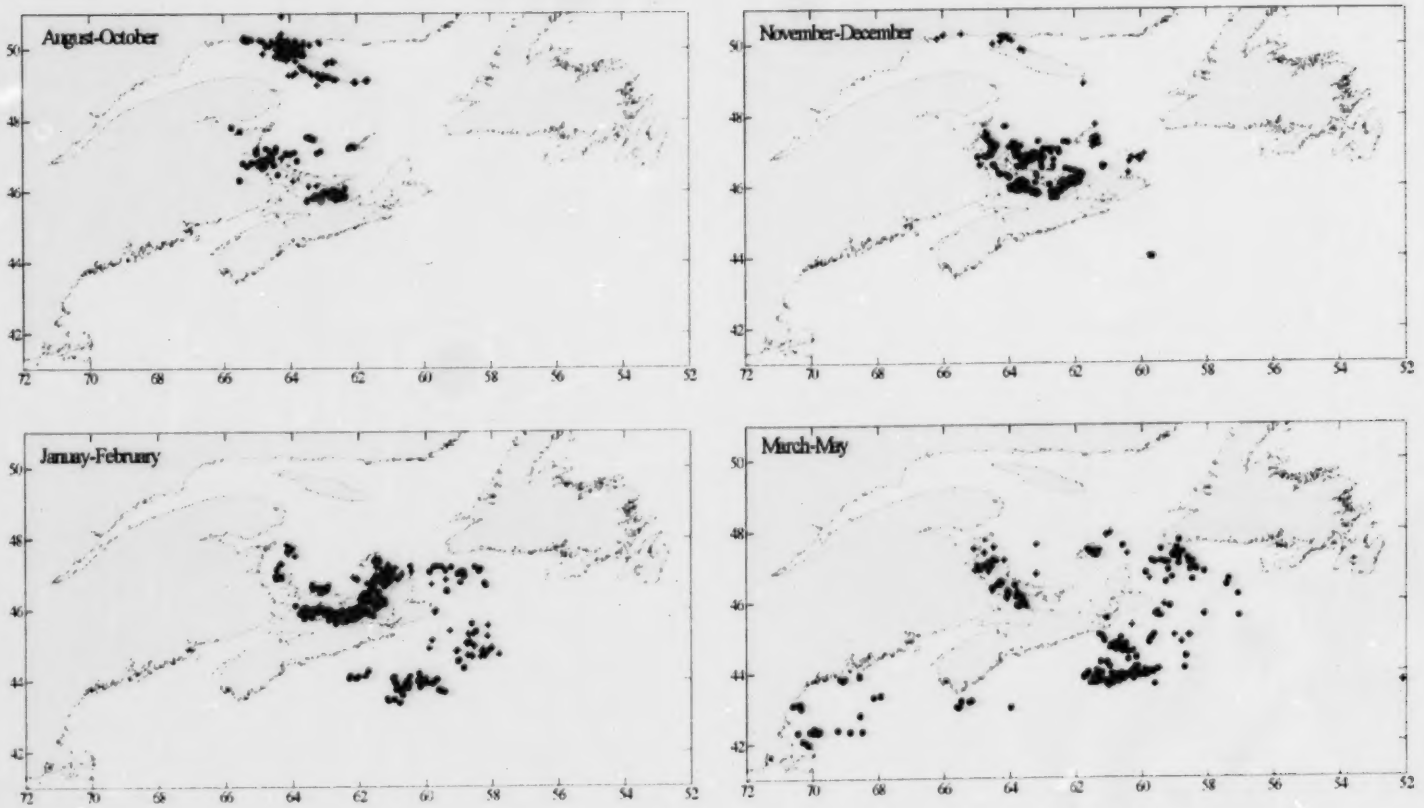

Figure 5. Bimonthly positions of 12 adult grey seals equipped with satellite transmitters in January 1993, August and September 1993 to 1997.

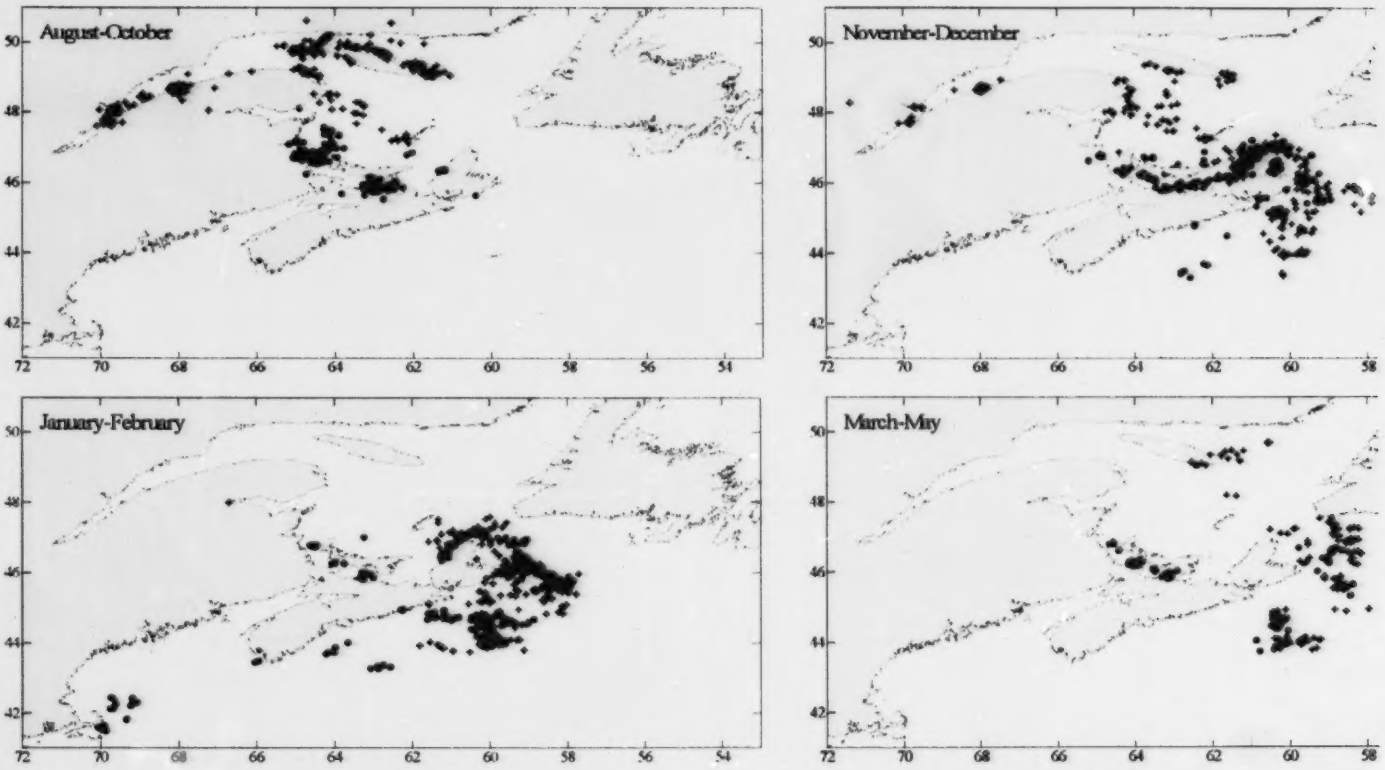

Figure 6. Bimonthly positions of 12 juvenile grey seals equipped with satellite transmitters in August and September 1994 to 1997 in the northern (+) and southern (•) Gulf of St Lawrence.

C. Diet

Studies of Grey seal diet in the Gulf have sampled from the Estuary (Les Escoumins), Anticosti Island in the northern Gulf, the Magdalen Islands, Miramichi Amet Island and Hillsborough Bay in the southern Gulf. Some of the sampling occurred during the 1950's and as in other species the methods have evolved in diet analyses making it difficult to examine changes over time.

Grey seal diet composition has been relatively well studied in the northern Gulf of St Lawrence (Benoit and Bowen 1990; Murie and Lavigne 1992; Proust 1996) and on the Scotian shelf (Mohn and Bowen 1996). In the northern Gulf, grey seals feed heavily on capelin, and lumpfish early in the summer (May to mid-July) and then feed more heavily on cod, herring and mackerel from late July into the fall. Overall , 32% (SE=9, N=4 years of samples) of the diet by weight may consist of cod in sampling conducted near Anticosti Island . Along the Eastern Shore, cod was found in 13% of the 143 stomachs collected between September and November 1988-90 and made up 19% of the reconstructed diet by weight. Near Sable Island, cod was found in only 6% of 393 faecal samples collected between 1991 and 1993 and made up 11% of the reconstructed diet by weight (Bowen et al 1993; Bowen and Harrison 1994). Grey seals feed on larger cod than do harp seals. In the northern Gulf, 27% of cod were ≤20 cm long, 39 % were 20-30 cm, 20% were 30-40 cm, and 14% > than 40 cm (Benoit and Bowen 1990). However, interannual variability in the frequency of size ranges does occur. For example in 1988, the length frequency of samples from the same area as Benoit and Bowen (1990), was 22%, 20%, 17% and 41 % for the length classes ≤20 cm, 20-30 cm, 30-40 cm and > 40 cm respectively, while in 1992 the distribution was 7%, 6%, 30% and 57% (Proust 1996).

Sampling has been more limited in the southern Gulf (Table 4). Cod was found in 14% of 89 food containing grey seal stomachs collected between the 1950's and 1970's, (Benoit and Bowen 1990). In samples collected in Northumberland Strait since 1992, cod was found in 7% of the stomachs (N=12), but formed less than 1% of the diet by weight, while in 6 food containing stomachs collected from the Magdalen Islands in late fall, cod was found in 3 and formed 16% of the diet by weight.

It is possible to develop some insights into what cod consumption by grey seals in 4T could be. If we assume that the importance of cod in the diet of grey seals in 4T is similar to that of grey seals on the Scotian Shelf then an average of published data indicates that cod from the Atlantic side of Nova Scotia forms a proportion of 0.15 (SE=.035, N=13 samples, where a sample is a month or season) of the diet by weight (Mohn and Bowen 1996). Assuming also that grey seals are distributed as in Table 3, that the rate of increase for Sable Island grey seals is 11.9 and that daily energy requirements of an individual seal can be described by a simple energy budget (Hammill and Stenson 1997) :

$$GEI_i = GP_i * (AF * 293 * BM_i^{0.75}) / ME_i$$

where GEI is daily gross energy intake (kjoules/d) at age i, and GP is the additional energy required by young seals.

Table 4. Prey species in the diet of grey seals from the Magdalen Islands and Amet Island in Northumberland Strait (frequency of occurrence). Food remains were found in 6/31, 12/12 , 4/4 and 13/14 animals collected from the Magdalen Islands (December) and from Amet Island (June and September) in 1994, 1995 and 1997 respectively. Another 13 animals were collected in October 1998, but this material has not been examined.

	Magdalen Islands				Amet Island			
	1992		1994		1995		1997	
Fish species	n	%	n	%	n	%	n	%
Winter Flounder			12	100	4	100	12	92.3
Yellowtail Flounder	1	16.7	2	16.7	1	25	2	15.4
American Plaice	3	50						
Pleuronectidae							6	46.2
Windowpane			9	75	4	100	9	69.2
Longhorn Sculpin			4	33.3	1	25	11	84.6
Shorthorn Sculpin	1	16.7	1	8.3				
Sculpin sp.					2	50	1	7.7
Smelt			4	33.3			3	23.1
Capelin	1	16.7						
Sand Lance	2	33.3						
Atlantic Herring	3	50	2	16.7			3	23.1
White Hake					1	25	2	15.4
Atlantic Cod	3	50	2	16.7	1	25	1	7.7
Gadidae			1	8.3			1	7.7
unidentified sp.	2	33.3	3	25	2	50	7	53.8
Totals	***6***	***100***	**12**	***100***	***4***	***100***	**13**	***100***

GP was set at 1.8, 1.6, 1.4, 1.3, 1.1, 1.1, and 1.0 for animals aged 0, 1, 2, 3, 4, 5, and ≥6 yrs respectively (Olesiuk, 1993). The activity factor (AF) was assumed to be 2 (Worthy, 1990), to approximate the average daily energy requirements as a multiple of the basal metabolic rate ($293*BM_i^{0.75}$; Kleiber 1975), where BM is body mass in kg. The metabolizable energy (ME_i) was set at 0.83 (Ronald *et*

al., 1984), assuming that seals consume primarily fish. Then cod consumption in 1999 is of the order of 5,000 to 9,000 t using the estimate of 0.15 for the fraction of cod in the diet and 0.15 plus 1S.E. if the Gulf component grey seal component is increasing at a rate of 3.4% . If the Gulf component is increasing at a greater rate than r=3.4 eg r=6.5 (Hammill 1999) then cod consumption would be on the order of 8,000 to 13,000 t (Fig. 7). The actual number of fish consumed will depend on the length frequency distribution applied, which as shown above can vary between years and also the weight-length relationships which at least in the northern Gulf have shown strong interannual variations (Lambert and Dutil 1997).

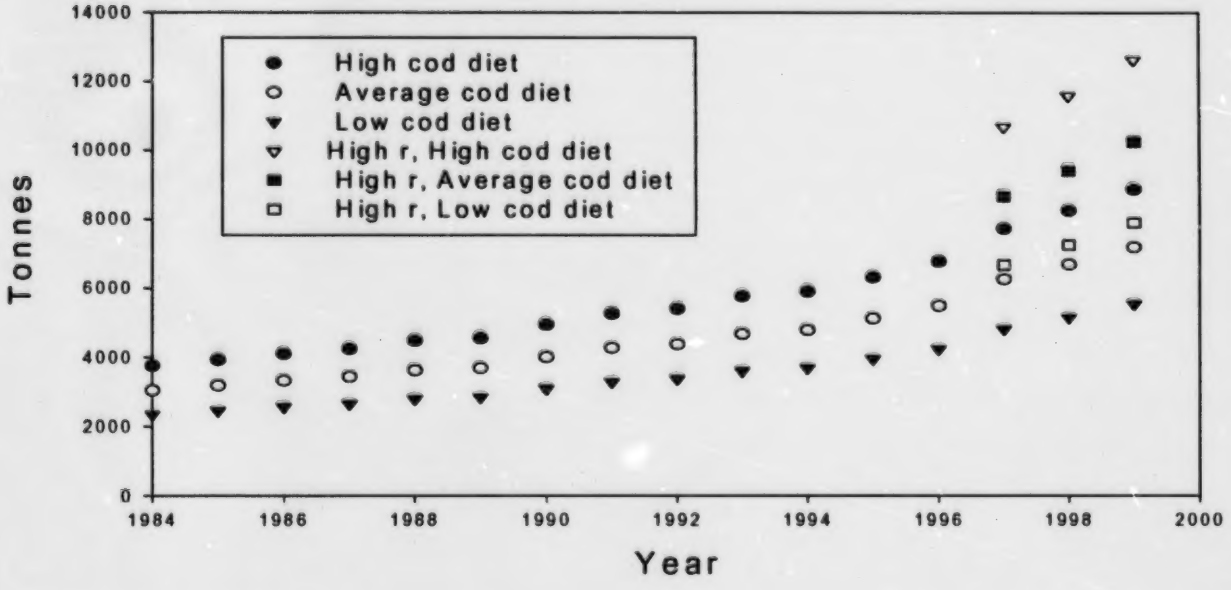

Figure 7. Estimated cod consumption by grey seals in 4T, assuming that cod comprises an average of 15% of the diet by weight and the grey seal population is increasing at r=11.9 for Sable Island grey seals and 3.4 for Gulf grey seals. High and Low cod diets represent the average proportion of cod ± 1 SE. High r (r=6.5) is r plus 1 S.E. (Hammill 1999) for Gulf grey seals while r for Sable Island grey seals does not change.

IV. Harbour seals

A. Abundance

Harbour seals were subjected to a bounty important impact on population abundance, but this species has never been completely surveyed in Atlantic Canada. Based on index reports, known removals and information on reproductive rates, Hammill and Stenson (In press) modelled harbour seal population abundance and concluded that the Atlantic population was in the neighbourhood of 30,000 animals. Harbour seals are currently protected from hunting except under conditions where permits are given for damage to aquaculture interests.

B. Biology, distribution and movements

Harbour seals are the smallest of the 4 pinniped species. Males and females are similar in size and may weigh about 100 kg during the breeding season. Harbour seals pup during May-July. Unlike the other species the pups enter the water and follow the females around soon after birth. Lactation is relatively long compared to many pinnipeds lasting for about 29 days. Harbour seals are characterised as a coastal species. They may move into rivers, but are often seen associated with reefs and rocks exposed at low tide which they use as haul-out sites. Harbour seals differ from the other 3 species in that they are very characteristically non-migratory. Some movement from summer regions may occur, especially in response to ice formation (Lesage and Hammill unpublished data), but compared to the other species these movements are limited. Foraging often occurs relatively close to these sites.

C. Diet

No information is available on diet composition in the gulf, but off Nova Scotia herring, pollock and squid are major prey items(Table 5). Hammill and Stenson (In press) did not think that harbour seals were important consumers of commercial fish, because of their small population size. Out of the estimated 4 million tons of prey consumed by all seal species in 1996, harbour seal consumption accounted for ≈ 0.1% of this consumption. However, recent work around Prince Edward Island indicates that harbour seals are more important than other species in causing damage to some fish gear, particularly smelt traps that are set near river mouths.

Table 5. Harbour seal diet composition (% wet weight) on the Scotian shelf and in the Bay of fundy (Bowen and Harrison 1996).

Species	Annual
Atlantic cod	5.7
Herring	24.4
Capelin	5.5
Mackerel	1.4
Sculpin	0.2
Haddock	0.1
Winter flounder	1.3
Cunner	0.3
Redfish	0.4
Pollock	12.7
Alewife	1.7
Ocean pout	0.8
Silver hake	0.7
Squid	14.8
White hake	2.9
Blueback herring	0.1
Other Fish	19.1
Butterfish	0.1
Fourspot flounder	0.1
Crab	0.4
Other Invert.	6.3
Mean energy (kj/g)	5.32

II. Discussion

Marine mammals can have a negative impact on fisheries by directly damaging gear, destroying or removing fish from gear, or by reducing the availability of fish to fishermen through predation on a species or its prey. In Canada, whale-fisheries interactions have not been addressed, but owing to their large size and/or abundance, predation by whales may not be negligible. The role of seal predation and its impact on commercial fisheries has been controversial. Populations of harp, and grey seal have increased over the last 30 years (Stenson et al 1995; Mohn and Bowen 1996) and these increases have been accompanied by an increase in damage to catches and gear particularly in the Magdalen Islands. In 1999-2000, there are plans to quantify this damage .

Assessing the role that marine mammals play in reducing the abundance of fish to commercial fisheries is complex because it must be placed within the context of total mortality. To do this, information on the abundance, diet composition, energy requirements, and spatial distribution of both predator and prey are required.

Several studies have quantified seal predation on fish in Atlantic Canada (Hammill et al. 1995; Mohn and Bowen 1996; Hammill and Stenson 1997), but work to place this predation within the context of total mortality has been limited. In other ecosystems predation by other species, particularly other fish often exceeds predation by marine mammals by a considerable amount (Overholtz et al. 1991; Trites et al. 1997). The development of a mass-balance model would be one step in the direction of ecosystem modelling, where mortality from seal predation could be assessed in terms of other sources of mortality and would also help to underline information gaps.

Hammill and Stenson (1997) estimated that seals consumed approximately 3.4 million tonnes of prey in 1996 in Atlantic Canada. Harp seals were the most important predator accounting for 80% of the total predation, followed by grey and hooded seals which accounted for 9% of total prey consumtion each, while harbour seals accounted for <1%. Within the Gulf of St Lawrence, grey seals and harp seals are the most important predators accounting for almost all of the estimated 800,000 t of prey consumed.

Harp and grey seals are found throughout NAFO Divisions 4R,S, and T. However, in the earlier study by Hammill and Stenson (1997), predation by harp seals was attributed to NAFO Divisions 4R,S owing to the absence of information on how to partition the herd within the Gulf. Since this earlier study no new information has been obtained on the seasonal distribution of harp seals in the Gulf. Attempts to partition the herd are based on assumptions that may be totally unreasonable. For example the movement of the single satellite tagged animal from Blanc Sablon, down the west coast of Newfoundland and out through Cabot Strait to the tail of the Banks was not expected and illustrates how little we know about the distribution of harp seals in the Gulf. Owing to the large size of the Northwest Atlantic harp seal population (5 million animals in 1994), errors in the distribution of animals will have a major impact on estimates of fish consumption by this species in the Gulf.

The importance of harp seal predation on groundfish in 4T cannot be evaluated. On the one hand the majority of harp seals do not move into the Gulf until the beginning of December, when the majority of cod have moved into Cabot Strait. Also, the limited diet data that do exist for 4T suggests that groundfish consumption by harp seals may not be important (Sergeant 1973; Stewart and Murie 1986; Murie and Lavigne 1991; Beck et al 1993), but it must be emphasized that this data is strongly biased towards sampling in March when harp seals feed very little and cod are not present in the Gulf.

Grey seal abundance has changed markedly over the last three decades, particularly on Sable Island where the herd appears to be increasing at a rate of about 13% (Mohn and Bowen 1996). Information on trends in the Gulf component of the NW Atlantic grey seal are more uncertain. Recent aerial

survey and mark-recapture estimates suggest that this component is increasing at an annual rate of 3.4%, but the confidence limits around this trajectory are large (between 0 and 6.5%). Cod consumption in 1999 by grey seals in 4T could be on the order of 5,000 to 13,000 tonnes, but as indicated by the wide range, there is a high degree of uncertainty associated with these estimates. In addition to the variability associated with the size of the Gulf component and its rate of change, data on the relative distribution of grey seals outside of the breeding season is limited. However, perhaps the most important difficulty in trying to estimate grey seal cod consumption in 4T is that very little information exists on diet composition in the southern Gulf . Sampling has been hindered by limited resources, the high human population density which limits large scale collections, and the absence of a grey seal hunting tradition in the southern Gulf. Increased effort is being directed towards this region, but progress will be slow.

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Literature cited

Baker, S.R., C. Barrette, and M.O. Hammill. 1995. Mass transfer during lactation of an ice-breeding pinniped, the grey seal (Halichoerus grypus), in Nova Scotia, Canada. J. Zool. (Lond)236:531-542.

Beck, G. G., T. G. Smith, and M. O. Hammill. 1993b. Evaluation of body condition in the Northwest Atlantic harp seal (Phoca groenlandica). Can. J. Fish. Aquat. Sci. 50: 1372-1381.

Beck, C. G., M. O. Hammill and T. G. Smith. 1993a. Seasonal variation in the diet of harp seals (Phoca groenlandica) from the Gulf of St. Lawrence and western Hudson Strait. Can. J. Fish. Aquat. Sci. 50:1363-1371.

Benoit, D. and W. D. Bowen. 1990. Summer diet of grey seals (*Halichoerus grypus*) at Anticosti Island, Gulf of St Lawrence, Canada. pp227-242. In W. D. Bowen (ed.) Population biology of sealworm (*Pseudoterranova decipiens*) in relation to its intermediate and seal hosts. Can. Bull. Fish. Aquat. Sci. **222**: 306p.

Bowen, W.D. and G.D. Harrison. 1994. Offshore diet of grey seals, *Halichoerus grypus*, near Sable island, Canada. Mar. Ecol. Prog. Ser. 112:1-11.

Bowen, W.D., J.W. Lawson and B. Beck. 1993. Seasonal and geographic variation in the species composition and prey size of prey consumed by

grey seals *Halichoerus grypus* on the Scotian Shelf. Can. J. Fish. Aquat. Sci. 50:1768-1778.

Bowen, W. D. and G. D. Harrison. 1996. Comparison of harbour seal diets in two inshore habitats of Atlantic Canada. Can. J. Zool. 74:125-135.

Bowen, W.D., R. Mohn and J. McMillan. 1999. Grey seal pup production on Sable Island: sustained exponential growth of a large mammal population. WP99/9 presented at the National Marine Mammal Peer Review Meeting in Montreal, 1-5 February 1999. 35 pp.

Clay, D. and G. Nielsen. 1983. Grey seal (*Halichoerus grypus*) distribution during 1983/84 in the gulf of St Lawrence as observed by aerial survey. Can. MS rep. Fish. Aquat. Sci. 1836: iii + 8 p.

Hammill, M.O. 1993. Distribution and movements of hooded seals tagged in the Gulf of St. Lawrence. Polar Biol. 13:307-310.

Hammill, M.O. 1999. Replacement Yields of Northwest Atlantic Grey seals (*Halichoerus grypus*). WP99/11 presented at the National Marine Mammal Peer Review Meeting in Montreal, 1-5 February 1999. 16 pp.

Hammill, M.O., M. Ryg and B. Mohn. 1995. Consumption of cod by the Northwest Atlantic Grey seal in Eastern Canada. pages 347-349 In A.S. Blix, L. Walloe and O. Ultang. Whales, seals fish and man. Proceedings the International symposium on the Biology of Marine Mammals in the Northeast Atlantic, Tromso, Norway. 29 Nov-1 Dec. 1994. Elsevier Science. New York.

Hammill, M.O. and G.B. Stenson. 1997. Estimated prey consumption by harp seals (*Phoca groenlandica*), grey seals (*Halichoerus grypus*), harbour seals (*Phoca vitulina*) and hooded seals (*Cystophora cristata*). NAFO SCR Doc. 97/40. 37 p.

Hammill, M.O., Stenson, G., Myers, R.A., and Stobo, W. 1998. Population trends of the grey seal (Halichoerus grypus) in the Gulf of St Lawrence. Can. J. Fish. Aquat. Sci.55:423-430.

Hammill, M.O., J.F. Gosselin, G.B. Stenson and B.J. Sjare. 1999. Non-Sable Island pup production of the Northwest Atlantic grey seal in 1996 and 1997. WP99/10 presented at the National Marine Mammal Peer Review Meeting in Montreal, 1-5 February 1999. 45 pp.

Hammill, M.O, C. Lydersen, K.M. Kovacs and B. Sjare. 1997. Estimated Fish consumption by hooded seals (Cystophora cristata) in the Gulf of St Lawrence. J. Northw. Atl. Fish. Sci. 22:249-257.

Hammill, M.O. and G.B. Stenson. (In press). Estimated prey consumption by harp seals (Phoca groenlandica), grey seals (Halichoerus grypus), Harbour seals (Phoca vitulina) and hooded seals (Cystophora cristata). J. Northw. Atl. Fish. Sci. 00:0000-0000.

Kleiber, M. 1975. The fire of life: An introduction to animal energetics. (2nd ed) R.E. Kreiger Publishing Co. New York.

Kovacs, K. M., D. M. Lavigne, and S. Innes. 1991. Mass transfer efficiency between harp seal (Phoca groenlandica) mothers and their pups during lactation. J. Zool., Lond. 223: 213-221.

Kovacs, K.M. and D.M. Lavigne. 1992. Mass-transfer efficiency between hooded seal (*Cystophora cristata*) mothers and their pups in the Gulf of St Lawrence. Can. J. Zool. 70:1315-1320.

Lambert, Y. and J.-D. Dutil. 1997. Condition and energy reserves on Atlantic cod (*Gadus morhua*) during the collapse of the northern Gulf of St Lawrence stock. Can. J. Fish. Aquat. Sci. 54:2388-2400.

Lavigueur, L., and M.O. Hammill. 1993. Distribution and seasonal movements of grey seals, Halichoerus grypus, in the Gulf of St. Lawrence. Can. Field Naturalist 107:329-340.

Lawson, J. W., G. B. Stenson, and D. G. McKinnon. 1995. Diet of harp seals (*Phoca groenlandica*) in nearshore waters of the northwest Atlantic during 1990-1993. Can J. Zool. **73**: 1805-1818.

Mohn, R., and Bowen, W.D. 1996. Grey seal predation on the eastern Scotian Shelf: modelling the impact on Atlantic cod. Can. J. Fish. Aquat. Sci. 53:2722-2738.

Murie,D.J. and D.M. Lavigne 1991. Food consumption of wintering harp seals, *Phoca groenlandica*) in the St Lawrence estuary, Canada. Can. J. Zool. 69:1289-1296.

Murie, D. J. and D. M. Lavigne. 1992. Growth and feeding habits of grey seals (*Halichoerus grypus*) in the Northwestern Gulf of St. Lawrence, Canada. Can. J. Zool. **70**:1604-1613.

Olesiuk, P. F. 1993. Annual prey consumption by harbour seals (*Phoca vitulina*) in the Strait of Georgia, British Columbia. Fisheries Bulletin (Dublin) **91**:491-515.

Overholtz, W.J., S.A. Murawski and K.L. Foster. 1991. Impact of predatory fish, marine mammals and seabirds on the pelagic ecosystem of the northeastern USA. ICES mar Sci. Symp. 193:198-208.

Proust, F. 1996. Composition du régime alimentaire du phoque gris (Halichoerus grypus) dans le Golfe du Saint-Laurent, Québec, Canada. Université du Québec à Rimouski, Rimouski, Quèbec, Canada. 72 p.

Ronald, K., K. M. Kiever, F. W. Beamish, and R. Frank. 1984. Energy requirements for maintenance and faecal and urinary losses of the grey seal (*Halichoerus grypus*). Can. J. Zool. **62**:1101-1105.

Sergeant, D.E. 1973. Feeding, growth and productivity of Northwest Atlantic harp seals (*Pagophilus groenlandicus*). J. Fish. Res. Board Can. 30:17-29.

Sergeant, D.E. 1976. History and present status of populations of harp and hooded seals. Biol. Cons. 10:95-118.

Sergeant, D. E. 1991. Harp seals, man and ice. Can. Spec. Publ. Fish. Aquat. Sci. 114: 153 p.

Stenson, G.B., M.O. Hammill, M.C.S. Kingsley, B. Sjare, W.G. Warren, and R.A. Myers. 1995. Pup production of harp seals, *Phoca groenlandica*, in the Northwest Atlantic during 1994. DFO Atlantic Res. Doc. 95/20. 32 pp.

G. B. Stenson, B. Healey, P. A. Shelton and B. Sjare. 1999. Recent Trends in the Population of Northwest Atlantic Harp Seals, *Phoca groenlandica*. Working paper WP99/6 presented to the National Marine Mammal Peer Review Committee meeting in Montreal, February 1-5 1999.

Stewart, R.E.A. and D.J. Murie. 1986. Food habits of lactating harp seals (Phoca groenlandica) in the gulf of St Lawrence in March. J. Mammal. 67:186-188.

Stobo, W.T., Beck, B., and Horne, J.K. 1990. Seasonal movements of grey seals (Halichoerus grypus) in the Northwest Atlantic. Pages 199-213 in Population biology of sealworm (Pseudoterranova decipiens) in relation to its intermediate and seal hosts. Edited by D.W. Bowen. Canadian Journal of Fisheries and Aquatic Sciences No 222. 306 p.

Trites, A.W., V. Christensen and D. Pauly. 1997. Competition between fisheries and marine mammals for prey and primary production in the Pacific Ocean. J. Northw. Atl. Fish. Sci. 22:173-187.

Winters, G.H. 1978. Production, mortality and sustainable yield of Northwest Atlantic harp seals (*Pagophilus groenlandicus*). J. fish. Res. Board Can. 35: 1249-1261.

Worthy, G. A. J. 1990. Nutritional energetics for marine mammals: Addendums. p. 489-520. In L.A. Dierauf (ed). CRC handbook of marine mammal medicine: Health, disease and rehabilitation. Boca Raton, Florida: CRC press.

Zwanenburg, K.C.T., and Bowen, W.D. 1990. Population trends of the grey seal (Halichoerus grypus) in Eastern Canada. Pages 185-197 in Population biology of sealworm (Pseudoterranova decipiens) in relation to its intermediate and seal hosts. Edited by D.W. Bowen. Canadian Journal of Fisheries and Aquatic Sciences No 222. 306 p.